SEISMIC HAZARD ZONE REPORT FOR THE AGUA DULCE 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

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5/31/05	BPS address correction, web link updates
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ILLUSTRATIONS

EXECUTIVE SUMMARY

This report summarizes the methods and sources of information used to prepare the Seismic Hazard Zone Map for the Agua Dulce 7.5-Minute Quadrangle, Los Angeles County, California. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area of approximately 37 square miles at a scale of 1 inch = 2,000 feet.

The center of the quadrangle is 13 miles east of Santa Clarita and 25 miles north of Los Angeles. The unincorporated rural communities of Agua Dulce and Soledad are in the northern half and the southern half lies within the Angeles National Forest. Zoning was limited mostly to developable areas. The Santa Clara River flows westward across the middle of the quadrangle within Soledad Canyon. Numerous south-trending creeks join the Santa Clara River. South of the canyon the steep north-facing slope of the San Gabriel Mountains, which rise above 4,900 feet, is deeply dissected by canyons in crystalline basement rocks. North of Soledad Canyon the terrain contrasts with that to the south because it developed upon sedimentary strata rather than basement rocks. Spectacular tilted “flatirons” of sandstone occur within Vasquez Rocks County Park, north of the Antelope Valley Freeway (State Highway 14). Access to the region is via the freeway, Soledad Canyon Road, Escondido Canyon Road, Agua Dulce Road and Forest Service roads in the national forest. At present, development is limited to rural homes and small ranches, mining for aggregate in Soledad Canyon, and recreational facilities in Soledad Canyon.

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years.

In the Agua Dulce Quadrangle the liquefaction zone is restricted to the bottoms of canyons, especially along the Santa Clara River and Agua Dulce Canyon. Although actual landslides are scarce in the Agua Dulce Quadrangle steep slopes are very common in the deeply dissected topography of the region. The earthquake-induced landslide zone covers about 33 percent of the evaluated portion of the quadrangle.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available for purchase from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) (now called California Geological Survey [CGS]) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Zone Report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historical ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Agua Dulce 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Agua Dulce 7.5-Minute Quadrangle, Los Angeles County, California

By
Elise Mattison, Janis L. Hernandez, and Allan G. Barrows

California Department of Conservation
California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) (now called California Geological Survey [CGS]) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997b). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997b), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC).

The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Agua Dulce 7.5-Minute Quadrangle. Section 2 (addressing earthquake-induced landslides) and Section 3 (addressing potential ground shaking) complete the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, including areas in the Agua Dulce Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill.

- Construction of shallow ground-water maps showing the historically highest known ground-water levels

- Information on potential ground shaking intensity based on CGS probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the SMGB (DOC, 2000).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Agua Dulce Quadrangle mainly consist of alluviated valleys and canyons. CGS's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Agua Dulce Quadrangle covers about 62 square miles in central Los Angeles County. The center of the area is 13 miles east of the Santa Clarita Civic Center and 25 miles north of the Los Angeles Civic Center. The entire quadrangle consists of unincorporated Los Angeles County land. The northern half contains the rural communities of Agua Dulce and Soledad. The southern half of the quadrangle lies within the Angeles National Forest. About 37 square miles of the quadrangle were evaluated for zoning.

The Santa Clara River flows westward across the middle of the quadrangle within Soledad Canyon. South of the canyon the steep north-facing slope of the San Gabriel Mountains contains deeply dissected canyons in crystalline basement rocks. Elevations along the crest of the mountains exceed 4,900 feet. The lowest elevation in the quadrangle is about 1,700 feet on the Santa Clara River at the western boundary. North of Soledad Canyon the physiography contrasts with that to the south because it developed upon sedimentary strata rather than basement rocks. The terrain is typically brushy and of lower relief than the San Gabriel Mountains, although spectacular tilted “flatirons” of sandstone are exposed within Vasquez Rocks County Park, which covers about one square mile north of the Antelope Valley Freeway. Numerous south-trending creeks join the Santa Clara River. The largest creek drains south-trending Agua Dulce Canyon and Sierra Pelona Valley near the northern boundary.

Access to the region is via the Antelope Valley Freeway (State Highway14), Soledad Canyon Road, Escondido Canyon Road, Agua Dulce Road and Forest Service roads in the national forest. At present, development is limited to rural homes and small ranches, and aggregate mining and recreational facilities in Soledad Canyon.

GEOLOGY

Bedrock and Surficial Geology

Late Quaternary alluvial and fluvial sedimentary deposits and artificial fill generally are susceptible to liquefaction. CGS evaluated the areal distribution of such deposits in the Agua Dulce Quadrangle using a geologic map obtained from the Dibblee Geological Foundation (Dibblee, 1996). CGS digitized the map and modified it by deleting landslide deposits and revising contacts between bedrock and surficial units to better conform to the topographic contours of the U.S. Geological Survey 7.5-minute quadrangle. Additional modifications reflect the more recent mapping in the area and include interpretations of observations made during the landslide inventory based upon aerial photographs and field reconnaissance (Plate 1.1). In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units.

Quaternary deposits in the Agua Dulce Quadrangle rest unconformably upon deformed Tertiary strata and crystalline basement complex rocks. They cover about six square miles, or about 16 percent of the evaluated part of the quadrangle, but less than 10 percent of the entire Agua Dulce Quadrangle (Plate 1.1). Pleistocene map unit Qoa covers approximately half the study area and was mapped as Quaternary deposits and includes scattered unconsolidated alluvial deposits, especially in Sierra Pelona Valley (Dibblee, 1996). Younger units consist of alluvial gravel containing sand and silt (Qa) and gravel and sand in the bed of the Santa Clara River, Agua Dulce Creek, and other drainage channels (Qg). Modern fill (af) from road construction and other operations occurs in places scattered across the area.

The bedrock geology of the Agua Dulce Quadrangle consists of Precambrian to Mesozoic crystalline rocks and Tertiary sedimentary and volcanic formations. The southern half of the map area consists almost entirely of crystalline rocks that belong to the large, regional San Gabriel anorthosite-gabbro complex of Precambrian age (Oakshott, 1958; Ehlig, 1975; Carter, 1980; 1982). Outcrops of light gray augen gneiss, among the oldest rocks in the quadrangle (Ehlig, 1975), occur in the northwestern corner of the map, where they have been intruded by light tan granitic rocks of late Mesozoic age (Dibblee, 1996). The crystalline rocks exposed in the northeastern portion of the quadrangle consist of syenite and anorthosite and a very small area of granodiorite (Dibblee, 1996).

Unconformably overlying the ancient basement rocks is a thick sequence of Tertiary sedimentary and volcanic rocks. See the earthquake-induced landslide portion of this report (Section 2) for further details.

Structural Geology

The dominant structural element within the quadrangle is the Soledad Basin, which is a southwest-plunging syncline that includes strata of the Vasquez, Tick Canyon, and Mint Canyon formations (Oakeshott, 1958). Minor folds and subparallel faults disrupt the symmetry of the Soledad Basin, particularly on the northern limb near Tick Canyon. Numerous northeast-striking left-lateral faults cut across the sedimentary rocks of the Soledad Basin and the basement rocks in the San Gabriel Mountains. These faults include the Lone Tree, Magic Mountain, Pole Canyon, Agua Dulce, Green Ranch, Little Escondido, Elkhorn, Tick Canyon, and Mint Canyon faults. None of these faults has recognized Holocene surface fault displacement and, therefore, no fault rupture hazard zones have been delineated within the mapped area (DOC, 1997a).

GROUND WATER

Depth to ground water information is fundamental to liquefaction hazard studies. Liquefaction of subsurface sediments can result in ground failure that can cause damage to structures at the surface through differential settlement or lateral spreading. Liquefaction hazard may exist in areas where depth to ground water is 40 feet or less where saturation reduces the effective normal stress (Youd, 1973). Natural processes and human activities cause large fluctuations in ground-water levels over time, so it is impossible to specify conditions that will exist when ground shaking occurs. To address this uncertainty, CGS develops ground-water maps that show depths to historically shallowest levels recorded from water wells and boreholes. The resultant maps differ considerably from conventional ground-water maps that are based on measurements collected during a single season or year.

For purposes of seismic hazard zoning in the Agua Dulce study area, depth to shallow ground water in alluviated canyon environments is the elevation difference between the measured or estimated high water surface and the upper limit of adjacent liquefiable Quaternary deposits. Plate 1.2 shows a range of depth to historically shallowest ground water within the canyons because the map scale disallows detailed contour lines.

PART II

LIQUEFACTION POTENTIAL

Liquefaction can occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. CGS's method combines geotechnical analyses where available, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (DOC, 2000).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10 percent probability of exceedance over a 50-year period (DOC, 2000). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Agua Dulce study area, CGS has calculated PGAs of 0.51 to 0.6 g, resulting from earthquakes of magnitude 6.7 to 7.8. The PGA and magnitude values are based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the SMGB (DOC, 2000). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Agua Dulce Quadrangle is summarized below.

Areas of Past Liquefaction

No documentation of historic or paleoseismic liquefaction in the Agua Dulce Quadrangle was found during this study.

Artificial Fills

In the Agua Dulce Quadrangle, artificial fill areas large enough to show at the scale of mapping that consist of engineered fill for elevated freeways are considered to be properly engineered. Zoning for liquefaction in such areas depends on soil conditions in underlying strata. Non-engineered fills are commonly loose and uncompacted and the material varies in size and type. Such fills that may become saturated and that are not associated with freeways are zoned for liquefaction per above criterion 2.

Areas with Sufficient Existing Geotechnical Data

Geotechnical logs of boreholes in the Agua Dulce study area were not found during the data collection phase of this study.

Areas with Insufficient Existing Geotechnical Data

Alluvium of small channels (Qa) and gravel and sand of major stream channels (Qg) in the Agua Dulce study area are designated as “zones of required investigation” for liquefaction where considered saturated, based on above criterion 4b.

ACKNOWLEDGMENTS

The authors would like to thank Terilee McGuire and Bob Moscovitz for GIS support, and Barbara Wanish, Ross Martin, and Diane Vaughan who prepared the final liquefaction hazard zone maps and graphic displays for this report.

REFERENCES

California Department of Conservation, Division of Mines and Geology, 1997a, Fault rupture hazard zones in California: Division of Mines and Geology Special Publication 42, Supplements 1 and 2 added in 1999.

California Department of Conservation, Division of Mines and Geology, 1997b, Guidelines for evaluating and mitigating seismic hazards in California: Division of Mines and Geology Special Publication 117, 74 p.

California Department of Conservation, Division of Mines and Geology, 2000, Recommended criteria for delineating seismic hazard zones in California: Division of Mines and Geology Special Publication 118, 12 p.

Carter, Bruce, 1980, Structure and petrology of the San Gabriel anorthosite-syenite body, Los Angeles County, California: California Institute of Technology, Ph.D. thesis, 393 p.

Carter, Bruce, 1982, Field petrology and structural development of the San Gabriel anorthosite-syenite body, Los Angeles County, California *in* Cooper, J.D., *editor*, Geologic excursions in the Transverse Ranges: Geological Society of America Volume and Guidebook, Cordilleran Section, 78th annual meeting, p.1-53.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange, and Ventura counties, California: Bulletin of Seismological Society of America, v. 86, no. 5, p. 1,645-1,649.

Dibblee, T.W., Jr., 1996, Geologic map of the Agua Dulce Quadrangle, Los Angeles County, California: Dibblee Foundation Map DF-58, scale 1:24000.

Ehlig, P.L., 1975, Basement rocks of the San Gabriel Mountains, south of the San Andreas Fault, southern California *in* Crowell, J.C., *editor*, San Andreas Fault in southern California: California Division Mines and Geology Special Report 118, p. 177-186.

Oakeshott, G.B., 1958, Geology and mineral resources of San Fernando Quadrangle, Los Angeles County, California: California Division of Mines and Geology Bulletin 172, 147 p., map scale 1:62,500.

Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, Tianqing, Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology, Open-File Report 96-08; also U.S. Geological Survey Open-File Report 96-706, 33 p.

Seed, H.B., Idriss, I.M. and Arango, Ignacio, 1983, Evaluation of liquefaction potential using field performance data: Journal of Geotechnical Engineering, v. 109, no. 3, p. 458-482.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Southern California Earthquake Center, 1999, Recommended procedures for implementation of DMG Special Publication 117 guidelines for analyzing and mitigating liquefaction in California: Southern California Earthquake Center, University of Southern California, 63 p.

Tinsley, J.C., Youd, T.L., Perkins, D.M. and Chen, A.T.F., 1985, Evaluating liquefaction potential, *in* Ziony, J.I., *editor*, Evaluating earthquake hazards in the Los Angeles region — An earth science perspective: U.S. Geological Survey Professional Paper 1360, p. 263-316.

Youd, T.L., 1973, Liquefaction, flow and associated ground failure: U.S. Geological Survey Circular 688, 12 p.

Youd, T.L., 1991, Mapping of earthquake-induced liquefaction for seismic zonation: Earthquake Engineering Research Institute, Proceedings, Fourth International Conference on Seismic Zonation, v. 1, p. 111-138.

Youd, T.L. and Perkins, D.M., 1978, Mapping liquefaction-induced ground failure potential: Journal of Geotechnical Engineering, v. 104, p. 433-446.

SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Agua Dulce 7.5-Minute Quadrangle, Los Angeles County, California

By
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California Geological Survey

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps prepared by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/SHMPsp117.asp

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing landslide hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee in 1998 under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of landslide analysis, evaluation, and mitigation techniques (SCEC, 2002). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Agua Dulce 7.5-Minute Quadrangle. Section 1 (addressing liquefaction) and Section 3 (addressing earthquake shaking), complete the report, which is one of a series that summarizes the preparation of seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Landslides triggered by earthquakes historically have been a significant cause of earthquake damage. In California, large earthquakes such as the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes triggered landslides that were responsible for destroying or damaging numerous structures, blocking major transportation corridors, and damaging life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, areas underlain by loose, weak soils, and areas on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, including numerous hillside areas that have already been developed or are likely to be developed in the future. The opportunity for strong earthquake ground shaking is high in many parts of California because of the presence of numerous active faults. The combination of these factors constitutes a significant seismic hazard throughout much of California, including the hillside areas of the Agua Dulce Quadrangle.

METHODS SUMMARY

The mapping of earthquake-induced landslide hazard zones presented in this report is based on the best available terrain, geologic, geotechnical, and seismological data. If unavailable or significantly outdated, new forms of these data were compiled or generated specifically for this project. The following were collected or generated for this evaluation:

- Digital terrain data were used to provide an up-to-date representation of slope gradient and slope aspect in the study area

- Geologic mapping was used to provide an accurate representation of the spatial distribution of geologic materials in the study area. In addition, a map of existing landslides, whether triggered by earthquakes or not, was prepared

- Geotechnical laboratory test data were collected and statistically analyzed to quantitatively characterize the strength properties and dynamic slope stability of geologic materials in the study area

- Seismological data in the form of CGS probabilistic shaking maps and catalogs of strong-motion records were used to characterize future earthquake shaking within the mapped area

The data collected for this evaluation were processed into a series of GIS layers using commercially available software. A slope stability analysis was performed using the Newmark method of analysis (Newmark, 1965), resulting in a map of landslide hazard potential. The earthquake-induced landslide hazard zone was derived from the landslide hazard potential map according to criteria developed in a CGS pilot study (McCrink and Real, 1996; McCrink, 2001) and adopted by the State Mining and Geology Board (DOC, 2000).

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered from a variety of outside sources. Although the selection of data used in this evaluation was rigorous, the quality of the data is variable. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Due to limitations in methodology, it should be noted that these zone maps do not necessarily capture all potential earthquake-induced landslide hazards. Earthquake-induced ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. It should also be noted that no attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Agua Dulce Quadrangle, for more information on the delineation of liquefaction zones.

A significant portion of the land within the Agua Dulce Peak Quadrangle lies inside the boundary of the Angeles National Forest and, therefore, is not likely to be developed. However, scattered private landholdings, which could be developed in the future, lie within and near the edge of the national forest boundary. The area evaluated for earthquake-induced landslide hazards in the Agua Dulce Quadrangle extends, locally, into national forest land, but does not include all of it.

The remainder of this report describes in more detail the mapping data and processes used to prepare the earthquake-induced landslide zone map for the Agua Dulce Quadrangle. The information is presented in two parts. Part I covers physiographic, geologic and engineering geologic conditions in the study area. Part II covers the preparation of landslide hazard potential and landslide zone maps.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Agua Dulce Quadrangle covers about 62 square miles in central Los Angeles County. The center of the area is 13 miles east of the Santa Clarita Civic Center and 25 miles north of the Los Angeles Civic Center. The entire quadrangle consists of unincorporated Los Angeles County land. The northern half contains the rural communities of Agua Dulce and Soledad. The southern half of the quadrangle lies within the Angeles National Forest. About 37 square miles of the quadrangle were evaluated for zoning.

The Santa Clara River flows westward across the middle of the quadrangle within Soledad Canyon. South of the canyon the steep north-facing slope of the San Gabriel Mountains contains deeply dissected canyons in crystalline basement rocks. Elevations along the crest of the mountains exceed 4,900 feet. The lowest elevation in the quadrangle is about 1,700 feet on the Santa Clara River at the western boundary. North of Soledad Canyon the physiography contrasts with that to the south because it developed upon sedimentary strata rather than basement rocks. The terrain is typically brushy and of lower relief than the San Gabriel Mountains, although spectacular tilted “flatirons” of sandstone are exposed within Vasquez Rocks County Park, which covers about one square mile north of the Antelope Valley Freeway. Numerous south-trending creeks join the Santa Clara River. The largest creek drains south-trending Agua Dulce Canyon and Sierra Pelona Valley near the northern boundary.

Access to the region is via the Antelope Valley Freeway (State Highway14), Soledad Canyon Road, Escondido Canyon Road, Agua Dulce Road and Forest Service roads in the national forest. At present, development is limited to rural homes and small ranches, mining for aggregate in Soledad Canyon, and recreational facilities in Soledad Canyon.

Digital Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. An accurate slope gradient calculation begins with an up-to-date map representation of the earth's surface in the form of a digital topographic map. Within the Agua Dulce Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, prepared from the 7.5-minute quadrangle topographic contours based on 1956 and 1957 aerial photography, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy.

Areas that have undergone large-scale grading since 1957 in the hilly portions of the quadrangle were updated to reflect the new topography. A DEM reflecting this recent grading was obtained from an airborne interferometric radar platform flown in 2001, with an estimated vertical accuracy of approximately 1.5 meters (Intermap Corporation, 2002). An interferometric radar DEM is prone to creating false topography where tall buildings, metal structures or trees are present. The DEM used for the graded areas within the Agua Dulce Quadrangle underwent additional processing to remove these types of artifacts (Wang and others, 2001). Nevertheless, the final hazard zone map was checked for potential errors resulting from the use of the radar DEM and corrected if necessary. Graded areas where the radar DEM was applied are shown on Plate 2.1.

A slope map was made from each DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The DEM was also used to make a slope aspect map. The manner in which the slope and aspect maps were used to prepare the zone map will be described in subsequent sections of this report.

GEOLOGY

Bedrock and Surficial Geology

The bedrock geologic map used in this slope stability evaluation was obtained from the Dibblee Geological Foundation (Dibblee, 1996) and digitized by CGS staff for this study. Bedrock units are described in detail in this section. Quaternary surficial geologic units are briefly described here and are discussed in more detail in Section 1, Liquefaction Evaluation Report.

CGS geologists modified the digital geologic map in the following ways. Landslide deposits were deleted from the map so that the distribution of bedrock formations and the newly created landslide inventory would exist on separate layers for the hazard analysis. Contacts between bedrock and surficial units were revised to better conform to the topographic contours of the U.S. Geological Survey 7.5-minute quadrangle. The digital geologic map was also modified to reflect recent mapping in the area and to include interpretations of observations made during the aerial photograph landslide inventory and field reconnaissance. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to the development and abundance of landslides was noted.

The bedrock geology for the Agua Dulce Quadrangle consists of Precambrian to Mesozoic crystalline rocks and Tertiary sedimentary units. The southern half of the map area consists almost entirely of crystalline rocks that belong to the regionally extensive San Gabriel anorthosite-gabbro complex of Precambrian age (Oakshott, 1958; Ehlig, 1975; Carter, 1980; 1982). As depicted upon Dibblee's (1996) map, this zoned massif contains light gray to bright white anorthosite (map symbol an) and is host to scattered thin mafic and aplite dikes. Other crystalline rocks include a light gray leucogabbro (lgb), dark greenish brown, mafic complex of jotunite-norite-gabbro-diorite (jgb), and tan to light rusty brown syenite (sy). Small bodies of dark gray dioritic gneiss (dgn) that occur as inclusions in the anorthosite-gabbro complex are among the oldest rocks in the quadrangle.

Outcrops of light gray augen gneiss (map symbol agn), also among the oldest rocks in the quadrangle (Ehlig, 1975), occur in the northwestern corner of the map, where they have been intruded by light tan granitic rocks (gr) of late Mesozoic age (Dibblee, 1996). The crystalline rocks exposed in the northeastern portion of the quadrangle consist of syenite (sy) and anorthosite (an) and a very small area of early Triassic light gray Lowe Granodiorite (lgdh) with dark mottled biotite mica and hornblende clusters (Dibblee, 1996). The syenite (sy) in this area encloses a dark gray mica schist/mica-feldspar gneiss unit (msg) (Dibblee, 1996).

Unconformably overlying the crystalline basement rocks is a thick sequence of Tertiary sedimentary and volcanic rocks. The oldest unit is the Vasquez Formation of late Eocene (?) to early Miocene (?) age. The Vasquez Formation consists of non-marine alluvial flood plain and stream sediments, shallow lacustrine, and fanglomerate deposits of mostly red colored, gritty siltstone, arkosic sandstone, sedimentary breccia, claystone, mudstone, conglomerate, and interbedded subaerial andesitic volcanic rocks. Vasquez Formation rocks cover the northeastern quarter of the quadrangle as a series of southwest-dipping strata and interbedded volcanic flows, agglomerates, and breccias. Dibblee (1996) mapped many subunits in the Vasquez Formation including: dark brown andesitic flows and flow-breccia with white chalcedony veinlets (Tvb and Tva), and a variety of very light gray to tan and pink conglomerate/sedimentary breccia units (Tvca, Tvcal, Tvcg, Tvcgl, Tvcd, Tvcs, Tvcg). Additionally, other units include; red to pink and light gray arkosic sandstone and conglomerate (Tvss and Tvssl), and a 50-foot thick marker bed of gritty sandstone (Tvsb). The Vasquez Rocks County Park area near the northern map boundary features the spectacular tilted flatirons of reddish cross-bedded Vasquez sandstone strata (Tvss).

Tick Canyon Formation (map symbol Ttc, Ttcg) of early Miocene age rests unconformably upon the Vasquez Formation and crops out in the northwestern corner of the Agua Dulce Quadrangle. It consists mostly of poorly consolidated, coarse, dark gray conglomeratic sandstone (fanglomerate) (Ttcg) and lesser pinkish brown sandstone, siltstone, and reddish claystone (Ttc) of fluvial origin with interlayered lake beds (Dibblee, 1996).

Within the northwestern part of the Agua Dulce Quadrangle the lowermost middle Miocene part of the Mint Canyon Formation (Tmc where undifferentiated) rests upon the

Tick Canyon Formation within a syncline that plunges toward the southwest. Mint Canyon Formation consists of pinkish-gray, non-marine arkosic sandstone, siltstone, and conglomerate (Tmcv, Tmcl) and a coarse, reddish brown conglomerate/fanglomerate (Tmcg) (Dibblee,1996).

Quaternary surficial deposits unconformably overlie the deformed Tertiary strata and the crystalline basement complex. These include scattered unconsolidated older alluvium (Qoa), especially in Sierra Pelona Valley, alluvial gravel containing minor sand and silt (Qa) and loose gravel and sand in the modern Santa Clara River, Agua Dulce Creek, and other drainage channels (Qg).

The very scarce Pleistocene and/or Holocene landslide deposits (Qls) are discussed in a subsequent section. Modern fill (af), mostly related to road construction, occurs in scattered areas across the map. A more detailed discussion of the Quaternary deposits in the Agua Dulce Quadrangle can be found in Section 1.

Structural Geology

The dominant structural element within the quadrangle is the Soledad Basin, which is a southwest-plunging syncline that includes strata of the Vasquez, Tick Canyon, and Mint Canyon formations (Oakeshott, 1958). Minor folds and subparallel faults disrupt the symmetry of the Soledad Basin, particularly on the northern limb near Tick Canyon. Numerous northeast-striking left-lateral faults cut across the sedimentary rocks of the Soledad Basin and the basement rocks in the San Gabriel Mountains. These include the Lone Tree, Magic Mountain, Pole Canyon, Agua Dulce, Green Ranch, Little Escondido, Elkhorn, Tick Canyon, and Mint Canyon faults. None of these faults have recognized Holocene fault movements and, therefore, no fault rupture hazard zones have been delineated within the mapped area (DOC, 1997; 1999).

Landslide Inventory

As a part of the geologic data compilation, an inventory of existing landslides in the Agua Dulce Quadrangle was prepared by field reconnaissance, analysis of stereo-paired aerial photographs and review of previously published (Morton and Streitz, 1969) and unpublished (Hart, 2001) landslide mapping. Landslides were mapped at a scale of 1:24,000. For each landslide included on the map a number of characteristics (attributes) were compiled. These characteristics include the confidence of interpretation (definite, probable and questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Landslides rated as definite and probable were carried into the landslide zoning as described later in this report. Landslides rated as questionable were not included in the zoning due to the uncertainty of their existence. The completed landslide map was scanned, digitized, and the attributes were compiled in a database. A version of this landslide inventory is included with Plate 2.1.

Landslides are uncommon within the Agua Dulce Quadrangle. Most are shallow rock slides and debris slides of small to moderate size. A few large rock slides occur within the crystalline anorthosite rocks, near the Agua Dulce Canyon area.

Because it is not within the scope of the Act to review and monitor grading practices to ensure past slope failures have been properly mitigated, all documented slope failures, whether or not surface expression currently exists, are included in the landslide inventory.

ENGINEERING GEOLOGY

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, the geologic map units described above were ranked and grouped on the basis of their shear strength. Generally, the primary source for shear-strength measurements is geotechnical reports prepared by consultants on file with local government permitting departments. Shear-strength data for the units identified on the Agua Dulce Quadrangle geologic map were obtained from the Los Angeles County Public Works Department and the CGS Environmental Review Program files (see Appendix A). The locations of rock and soil samples taken for shear testing within the Agua Dulce Quadrangle are shown on Plate 2.1. Shear tests from the Mint Canyon, Acton, and Ritter Ridge quadrangles were evaluated for several geologic formations for which little or no shear test information was available within the Agua Dulce Quadrangle.

Shear strength data gathered from the above sources were compiled for each geologic map unit. Geologic units were grouped on the basis of average angle of internal friction (average phi) and lithologic character. Average (mean or median) phi values for each geologic map unit and corresponding strength group are summarized in Table 2.1. For each of the geologic strength groups (Table 2.2) in the map area, a single shear strength value was assigned and used in our slope stability analysis. A geologic material strength map was made based on the groupings presented in Table 2.1 and Table 2.2, and this map provides a spatial representation of material strength for use in the slope stability analysis.

The members of the Vasquez, Tick Canyon, and Mint Canyon formations were subdivided further to represent potential bedding plane failures, as described below.

Adverse Bedding Conditions

Adverse bedding conditions are an important consideration in slope stability analyses. Adverse bedding conditions occur where the dip direction of bedded sedimentary rocks is roughly the same as the slope aspect, and where the dip magnitude is less than the slope gradient. Under these conditions, landslides can slip along bedding surfaces due to a lack of lateral support.

To account for adverse bedding in our slope stability evaluation, we used geologic structural data in combination with digital terrain data to identify areas with potentially adverse bedding, using methods similar to those of Brabb (1983). The structural data, derived from the geologic map database, were used to categorize areas of common bedding dip direction and magnitude. The dip direction was then compared to the slope aspect and, if the same, the dip magnitude and slope gradient categories were compared.

If the dip magnitude category was less than or equal to the slope gradient category, but greater than 25 percent (4:1 slope), the area was marked as a potential adverse bedding area.

The Vasquez, Tick Canyon, and Mint Canyon formations, which contain interbedded hard (resistant) units, such as sandstone and basalt, and soft (weak) units, such as shale and claystone, were subdivided based on shear strength differences between coarse-grained (higher strength) and fine-grained (lower strength) lithologies. Shear strength values for the fine- and coarse-grained lithologies were then applied to areas of favorable and adverse bedding orientation, which were determined from structural and terrain data as discussed above. It was assumed that coarse-grained material strength dominates where bedding dips into a slope (favorable bedding) while fine-grained material strength dominates where bedding dips out of a slope (adverse bedding). The geologic material strength map was modified by assigning the lower, fine-grained shear strength values to areas where potential adverse bedding conditions were identified. The favorable and adverse bedding shear strength parameters for the above formations are included in Table 2.1.

As discussed later in this report, the criteria for landslide zone mapping state that all existing landslides that are mapped as definite or probable are automatically included in the landslide zone of required investigation. Therefore, an evaluation of shear strength parameters for existing landslides is not necessary for the preparation of the zone map. However, in the interest of completeness for the material strength map, to provide relevant material strength information to project plan reviewers, and to allow for future revisions of our zone mapping procedures, we have collected and compiled shear strength data considered representative of existing landslides within the quadrangle.

Existing Landslides

The strength characteristics of existing landslides (Qls) must be based on tests of the materials along the landslide slip surface. Ideally, shear tests of slip surfaces formed in each mapped geologic unit would be used. However, this amount of information is rarely available, and for the preparation of the earthquake-induced landslide zone map it has been assumed that all landslides within the quadrangle have the same slip surface strength parameters. We collect and use primarily “residual” strength parameters from laboratory tests of slip surface materials tested in direct shear or ring shear test equipment. Back-calculated strength parameters, if the calculations appear to have been performed appropriately, have also been used. Because no shear strength information for landslide slip surface materials was available within the Agua Dulce Quadrangle, a value of 16 degrees was adopted based on data from the adjacent Mint Canyon Quadrangle.

AGUA DULCE QUADRANGLE
SHEAR STRENGTH GROUPS

Geologic Material Strength Group	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	agn	2	38/38	38/39	200/354	msg,	38
	gr	5	37/37			dgn,	
	Tvcg (fbc)	5	41/40			lgb,	
	Tvcd (fbc)	3	41/41			jgb,	
	Tvssl (fbc)	2	40/40			lgdh,	
	Tvss (fbc)	7	37/39			Tvsb (fbc)	
	Ttcg (fbc)	7	38/39				
	Tmcg (fbc)	6	38/39				
GROUP 2	an	3	34/35	34/35	481/275	Tva (fbc),	34
	sy	26	34/35			Tvcd (abc),	
	Tvcal (fbc)	2	35/35			Tvcs (fbc),	
	Tvcgl (fbc)	7	34/35			Tvca (fbc),	
	Tvb (fbc)	28	34/34			Tvssl (abc),	
	Tvcg (abc)	4	34/35			Tvss (abc),	
	Ttc (fbc)	7	34/35			Tvsb (abc),	
	Tmcl (fbc)	3	35/34			Tmc (fbc)	
	Tmcv (fbc)	4	34/32				
	Qoa	23	35/36				
GROUP 3	Tvcgl (abc)	2	30/30	30/31	254/237	Tvcal (abc),	30
	Tmcl (abc)	2	29/29			Tvcs (abc),	
	Qa	3	28/32			Tvca (abc),	
	af	14	30/32			Ttcg (abc),	
						Ttc (abc),	
						Qg	
GROUP 4	Tvb (abc)	10	26/26	26/26	278/220	Tva (abc),	26
	Tmcg (abc)	1	26/26			Tmc (abc)	
	Tmcv (abc)	2	26/26				
GROUP 5	Qls*	16	16/15	16/15	390/253	Qls	16

abc = adverse bedding condition, fine-grained material strength

fbc = favorable bedding condition, coarse-grained material strength

*** = Value for Qls obtained from data used for Mint Canyon Quadrangle Zone Map**

Formation abbreviations for strength groups from Dibblee, 1996

Table 2.1. Summary of the Shear Strength Statistics for the Agua Dulce Quadrangle.

SHEAR STRENGTH GROUPS FOR THE AGUA DULCE 7.5-MINUTE QUADRANGLE				
GROUP 1	**GROUP 2**	**GROUP 3**	**GROUP 4**	**GROUP 5**
agn, msg, dgn, lgb, jgb, lgdh, gr, Tvcg (fbc), Tvsb (fbc), Tvcd (fbc), Tvssl (fbc), Tvss (fbc), Ttcg (fbc), Tmcg (fbc)	an, sy, Tvcal (fbc), Tvcgl (fbc), Tvb (fbc), Tva (fbc), Tvcg (abc), Tvcd (abc), Tvcs (fbc), Tvca (fbc), Tvssl (abc), Tvss (abc), Tvsb (abc), Ttc (fbc), Tmcl (fbc), Tmcv (fbc), Tmc (fbc), Qoa	Tvcgl (abc), Tvcal (abc), Tvcs (abc), Tvca (abc), Ttcg (abc), Ttc (abc), Tmcl (abc), Qa, Qg, af	Tvb (abc), Tva (abc), Tmcg (abc), Tmcv (abc), Tmc (abc)	Qls

Table 2.2. Summary of Shear Strength Groups for the Agua Dulce Quadrangle.

PART II

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Design Strong-Motion Record

To evaluate earthquake-induced landslide hazard potential in the study area, a method of dynamic slope stability analysis developed by Newmark (1965) was used. The Newmark method analyzes dynamic slope stability by calculating the cumulative down-slope displacement for a given earthquake strong-motion time history. As implemented for the preparation of earthquake-induced landslide zones, the Newmark method necessitates the selection of a design earthquake strong-motion record to provide the "ground shaking opportunity." For the Agua Dulce Quadrangle, selection of a strong motion record was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by CGS for a 10 percent probability of being exceeded in 50 years (Petersen and others, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.9 to 7.8
Modal Distance:	10.4 km to 21.8 km
PGA:	0.49 g to 0.64 g

The strong-motion record selected for the slope stability analysis in the Agua Dulce Quadrangle was the Southern California Edison Lucerne record from the 1992 magnitude 7.3 Landers, California, earthquake. This record had a source to recording site distance of 1.1 km and a peak ground acceleration (PGA) of 0.80g. Although the distance and PGA from the Lucerne record do not fall within the range of the probabilistic parameters, this record was judged to be sufficiently conservative to be used in the stability analyses. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

The design strong-motion record was used to develop a relationship between landslide displacement and yield acceleration (a_y), defined as the earthquake horizontal ground acceleration above which landslide displacements take place. This relationship was prepared by integrating the design strong-motion record twice for a given acceleration value to find the corresponding displacement, and the process was repeated for a range of acceleration values (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for the design strong-motion record. This curve provides the required link between anticipated earthquake shaking and estimates of displacement for different combinations of geologic materials and slope gradient, as described in the Slope Stability Analysis section below.

The amount of displacement predicted by the Newmark analysis provides an indication of the relative amount of damage that could be caused by earthquake-induced landsliding. Displacements of 30, 15 and 5 cm were used as criteria for rating levels of earthquake-induced landslide hazard potential based on the work of Youd (1980), Wilson and Keefer (1983), and a CGS pilot study for earthquake-induced landslides (McCrink and Real, 1996; McCrink, 2001). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations 0.14 g, 0.18 g, and 0.24 g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant in the Agua Dulce Quadrangle.

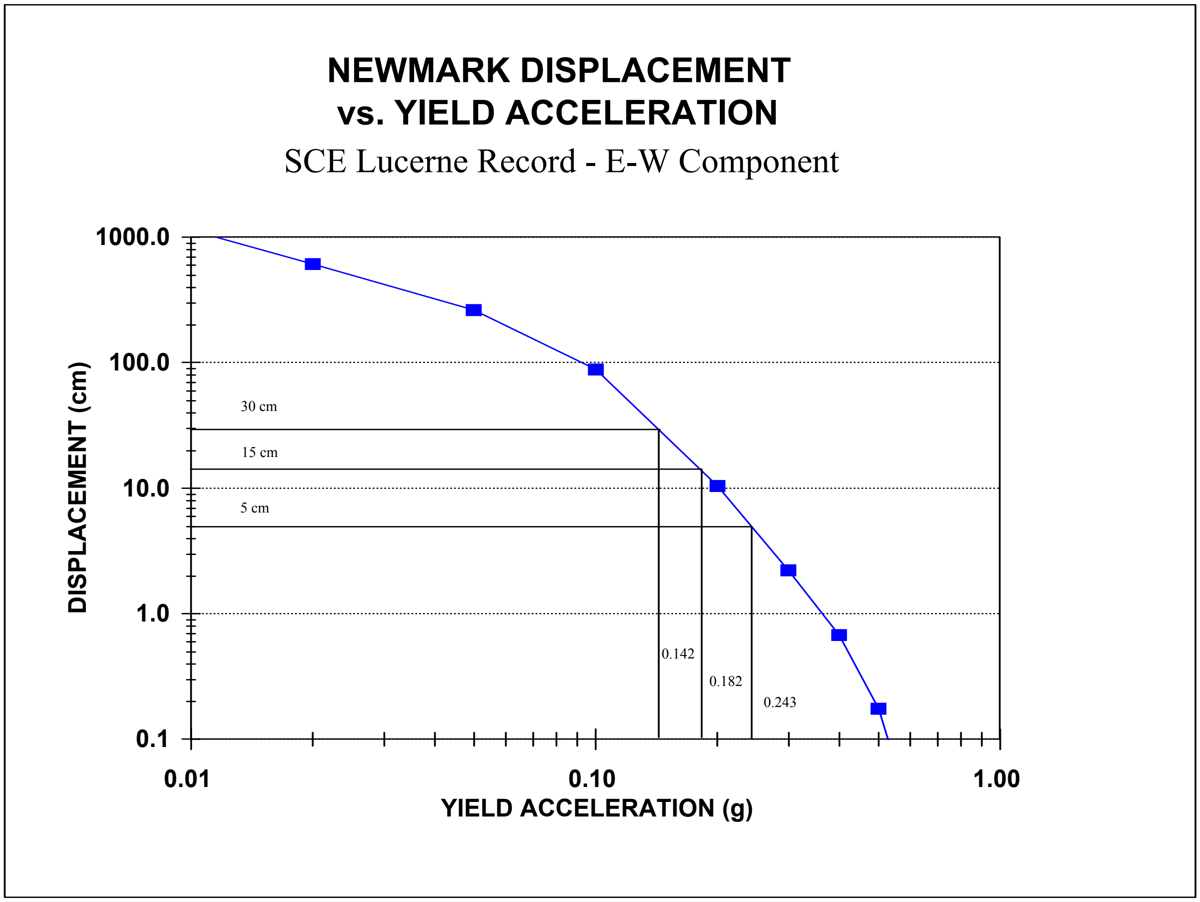

Figure 2.1. Yield Acceleration vs. Newmark Displacement for 1992 Landers Earthquake Lucerne Record.

Slope Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where **FS** is the Factor of Safety, **g** is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield accelerations resulting from Newmark's equations represent the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. Based on the relationship between yield acceleration and Newmark displacement shown in Figure 2.1, hazard potentials were assigned as follows:

1. If the calculated yield acceleration was less than 0.14 g, Newmark displacement greater than 30 cm is indicated, and a HIGH hazard potential was assigned (H on Table 2.3)

2. If the calculated yield acceleration fell between 0.14 g and 0.18 g, Newmark displacement between 15 cm and 30 cm is indicated, and a MODERATE hazard potential was assigned (M on Table 2.3)

3. If the calculated yield acceleration fell between 0.18 g and 0.24 g, Newmark displacement between 5 cm and 15 cm is indicated, and a LOW hazard potential was assigned (L on Table 2.3)

4. If the calculated yield acceleration was greater than 0.24 g, Newmark displacement of less than 5 cm is indicated, and a VERY LOW potential was assigned (VL on Table 2.3)

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

AGUA DULCE QUADRANGLE HAZARD POTENTIAL MATRIX				
Geologic Material Strength Group (Average Phi)	HAZARD POTENTIAL (Percent Slope)			
	Very Low	Low	Moderate	High
1 (38)	0 to 48%	48 to 57%	57 to 61%	> 61%
2 (34)	0 to 41%	41 to 48%	48 to 52%	> 52%
3 (30)	0 to 31%	31 to 37%	37 to 41%	> 41%
4 (26)	0 to 24%	24 to 29%	29 to 33%	> 33%
5 (16)	0 to 4%	4 to 10%	10 to 14%	> 14%

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Agua Dulce Quadrangle. Values in the table show the range of slope gradient (expressed as percent slope) corresponding to calculated Newmark displacement ranges from the design earthquake for each material strength group.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (DOC, 2000). Under these criteria, earthquake-induced landslide hazard zones are defined as areas that meet one or both of the following conditions:

1. Areas that have been identified as having experienced landslide movement in the past, including all mappable landslide deposits and source areas as well as any landslide that is known to have been triggered by historic earthquake activity.

2. Areas where the geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

These conditions are discussed in further detail in the following sections.

Existing Landslides

Existing landslides typically consist of disrupted soils and rock materials that are generally weaker than adjacent undisturbed rock and soil materials. Previous studies indicate that existing landslides can be reactivated by earthquake movements (Keefer, 1984). Earthquake-triggered movement of existing landslides is most pronounced in steep head scarp areas and at the toe of existing landslide deposits. Although reactivation of deep-seated landslide deposits is less common (Keefer, 1984), a significant number of deep-seated landslide movements have occurred during, or soon after, several recent earthquakes. **Based on these observations, all existing landslides with a definite or probable confidence rating are included within the earthquake-induced landslide hazard zone.**

Geologic and Geotechnical Analysis

Based on the conclusions of a pilot study performed by CGS (McCrink and Real, 1996; McCrink, 2001), it has been concluded that earthquake-induced landslide hazard zones should encompass all areas that have a High, Moderate or Low level of hazard potential (see Table 2.3). This would include all areas where the analyses indicate earthquake displacements of 5 centimeters or greater. Areas with a Very Low hazard potential, indicating less than 5 centimeters displacement, are excluded from the zone.

As summarized in Table 2.3, all areas characterized by the following geologic strength group and slope gradient conditions are included in the earthquake-induced landslide hazard zone:

1. Geologic Strength Group 5 is included for all slopes greater than 4 percent. (Note: The only geologic unit included in Geologic Strength Group 5 is Qls, existing

landslides. They have been included or excluded from the landslide zones on the basis of the criteria described in the previous section).

2. Geologic Strength Group 4 is included for all slopes steeper than 24 percent.
3. Geologic Strength Group 3 is included for all slopes steeper than 31 percent.
4. Geologic Strength Group 2 is included for all slopes steeper than 41 percent.
5. Geologic Strength Group 1 is included for all slopes greater than 48 percent.

This results in approximately 33 percent of the area mapped in the quadrangle lying within the earthquake-induced landslide hazard zone for the Agua Dulce Quadrangle.

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REFERENCES

Brabb, E.E., 1983, Map showing direction and amount of bedding dip of sedimentary rocks in San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1257C, 1 sheet, scale 1:62,500.

Bailey, T.H. and Jahns, R.H., 1954, Geology of the Transverse Range Province, southern California *in* Jahns, R.H, *editor*, Geology of Southern California: Division of Mines and Geology, Bulletin 170, Ch. 2, pt 6, p. 83-106.

California Department of Conservation, Division of Mines and Geology, 1997, Guidelines for evaluating and mitigating seismic hazards in California: Division of Mines and Geology Special Publication 117, 74 p.

California Department of Conservation, Division of Mines and Geology, 1997 and 1999, Fault rupture hazard zones in California: Division of Mines and Geology Special Publication 42, supplements 1 and 2 added 1999, 38 p.

California Department of Conservation, Division of Mines and Geology, 2000, Recommended criteria for delineating seismic hazard zones: Division of Mines and Geology Special Publication 118, 12 p.

Carter, Bruce, 1980, Structure and petrology of the San Gabriel anorthosite-syenite body, Los Angeles County, California: California Institute of Technology, Ph.D. thesis, 393 p.

Carter, Bruce, 1982, Field petrology and structural development of the San Gabriel anorthosite-syenite body, Los Angeles County, California *in* Cooper, J.D., *editor*, Geologic excursions in the Transverse Ranges: Geological Society of America Volume and Guidebook, Cordilleran Section, 78th annual meeting, p.1-53.

Dibblee, T.W., Jr., 1996, Geologic map of the Agua Dulce Quadrangle, Los Angeles County, California: Dibblee Foundation Map DF-58, scale 1:24000.

Ehlig, P.L., 1975, Basement rocks of the San Gabriel Mountains, south of the San Andreas Fault, southern California *in* Crowell, J.C., *editor*, San Andreas Fault in southern California: California Division Mines and Geology Special Report 118, p. 177-186.

Hart, Earl W., 2001, Landslide inventory of a portion of the Agua Dulce Quadrangle, Los Angeles County, California, Scale 1:24,000, unpublished.

Horn, B.K.P., 1981, Hill shading and the reflectance map: Proceedings of the IEEE, v. 69, no. 1, p. 14-47.

Intermap Corporation, 2002, Global Terrain product handbook and quick start guide: http://www.globalterrain.com/pdf%20files/GT_product_handbook_v2_3.pdf

Jibson, R.W., 1993, Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis: Transportation Research Board, National Research Council, Transportation Research Record 1411, 17 p.

Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, no. 4, p. 406-421.

McCrink, T.P., 2001, Mapping earthquake-induced landslide hazards in Santa Cruz County *in* Ferriz, H. and Anderson, R., *editors*, Engineering geology practice in northern California: California Geological Survey Bulletin 210 / Association of Engineering Geologists Special Publication 12, p.77-94.

McCrink, T.P. and Real, C.R., 1996, Evaluation of the Newmark method for mapping earthquake-induced landslide hazards in the Laurel 7-1/2 Minute Quadrangle, Santa Cruz County, California: California Division of Mines and Geology Final Technical Report for U.S. Geological Survey Contract 143-93-G-2334, U.S. Geological Survey, Reston, Virginia, 31 p.

Morton, D.M. and Streitz, Robert, 1969, Preliminary reconnaissance map of major landslides, San Gabriel Mountains, California: California Division of Mines and Geology Map Sheet 15, scale 1:62,500.

Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: Geotechnique, v. 15, no. 2, p. 139-160.

Oakeshott, G.B., 1958, Geology and mineral resources of San Fernando Quadrangle, Los Angeles County, California: California Division of Mines and Geology Bulletin 172, 147 p., map scale 1:62,500.

Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao. T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Division of Mines and Geology, Open-File Report 96-08; also U.S. Geological Survey Open-File Report 96-706, 33 p.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Southern California Earthquake Center, 2002, Recommended procedures for implementation of DMG Special Publication 117 guidelines for analyzing and mitigating landslide hazards in California: Southern California Earthquake Center, University of Southern California, 108 p.

U.S. Geological Survey, 1993, Digital Elevation Models: National Mapping Program, Technical Instructions, Data Users Guide 5, 48 p.

Wang, Y., Mercer, J.B., Tao, V.C., Sharma, J. and Crawford, S., 2001, Automatic generation of bald earth digital elevation models from digital surface models created using airborne IFSAR: http://www.intermaptechnologies.com/PDF_files/asprs2001_Intermap_E.pdf

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Youd, T.L., 1980, Ground failure displacement and earthquake damage to buildings: American Society of Civil Engineers Conference on Civil Engineering and Nuclear Power, 2d, Knoxville, Tennessee, 1980, v. 2, p. 7-6-2 to 7-6-26.

AIR PHOTOS

American Aerial Surveys, dated 6-19-80, Flight 80136, photo numbers; 36 – 39, 41, 79 – 93, scale 1:18,000.

American Aerial Surveys, dated 7-14-80, Flight 80165, photo numbers; 23 – 26, 27 – 30, 81 - 83, scale 1:24,000.

United States Department of Agriculture, Soil Conservation Service, dated 5/2/1940, Flight numbers; AXJ-307-79, 307-81, 307-83 and 307-85, approximate scale 1:20,000.

APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County Public Works	153
CGS Environmental Review Program	25
Total Number of Shear Tests	178

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Agua Dulce 7.5-Minute Quadrangle, Los Angeles County, California

By

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California Department of Conservation
California Geological Survey
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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (DOC, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.conservation.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10 percent probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

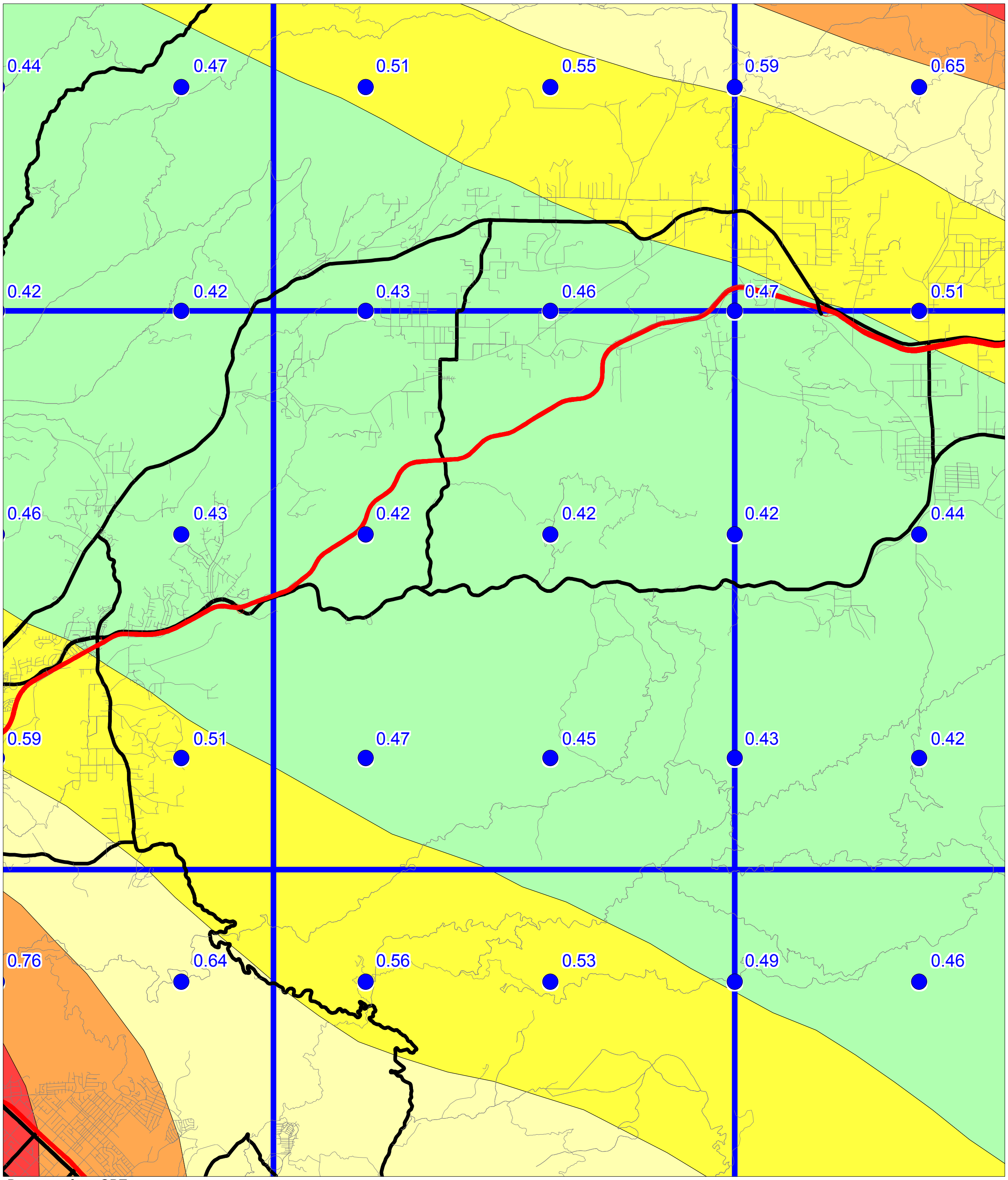
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight

AGUA DULCE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

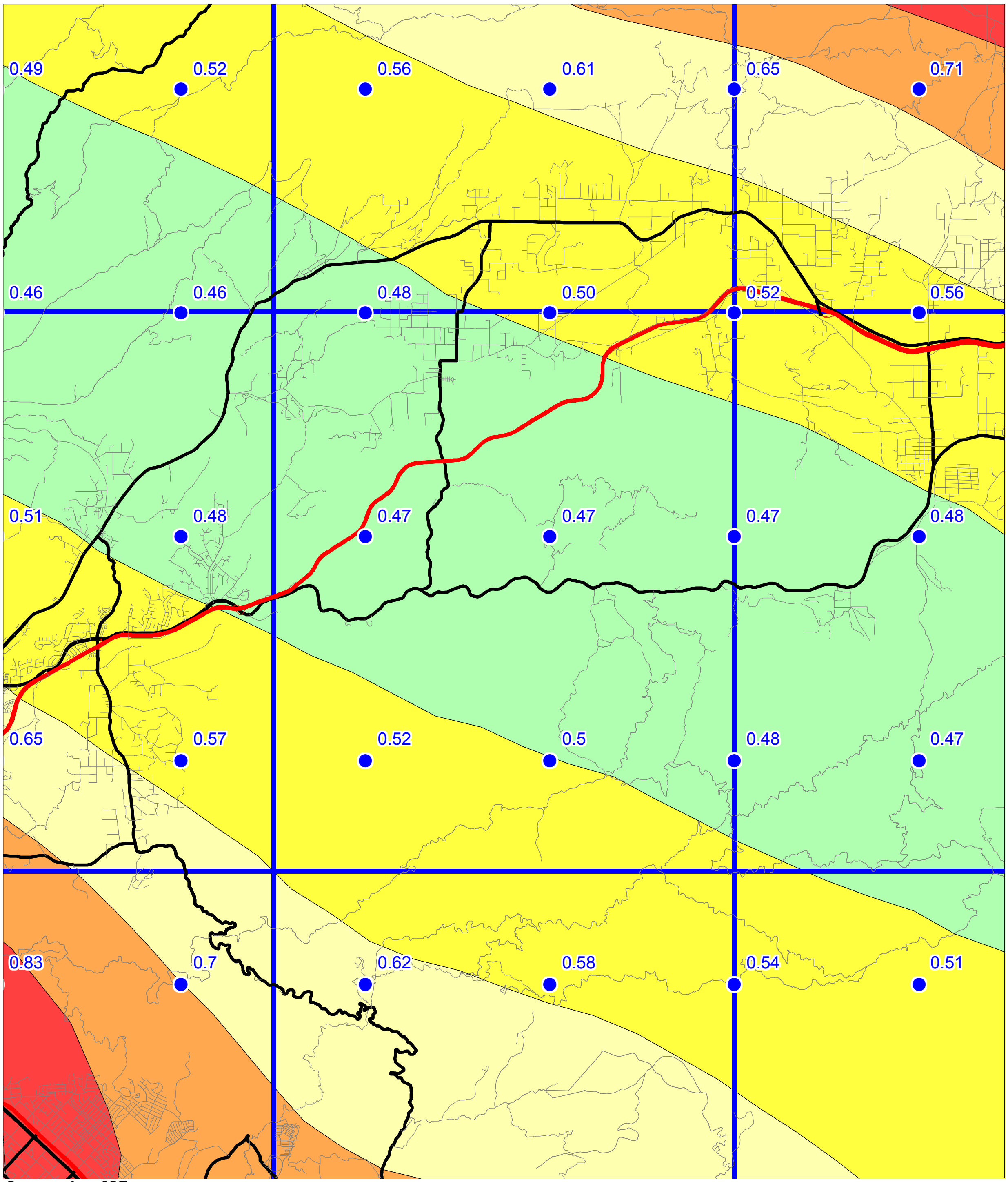
Figure 3.1

AGUA DULCE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

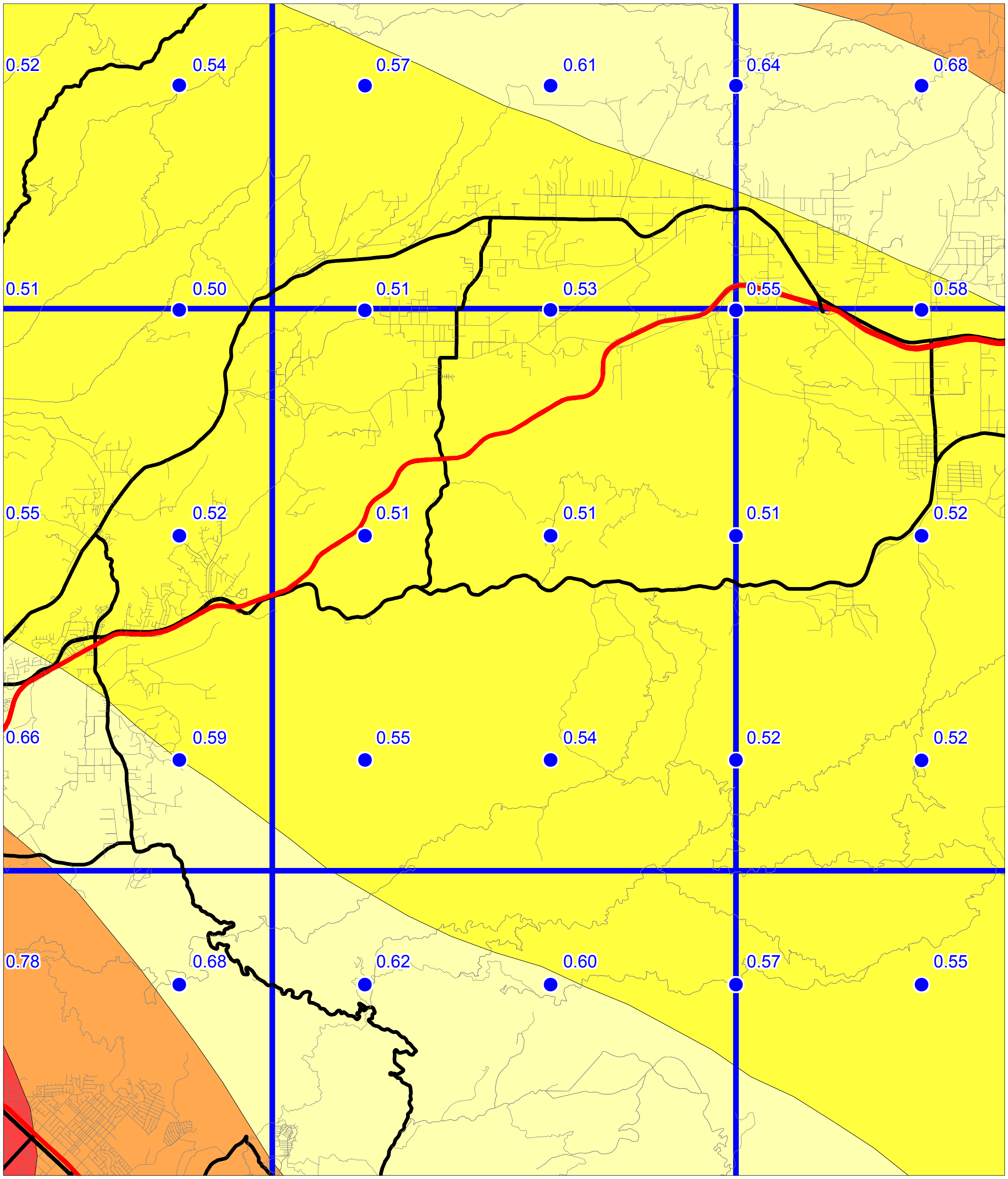
Figure 3.2

AGUA DULCE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

Figure 3.3

adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10 percent probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the "simplified Seed-Idriss method" of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a "magnitude-weighted" ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

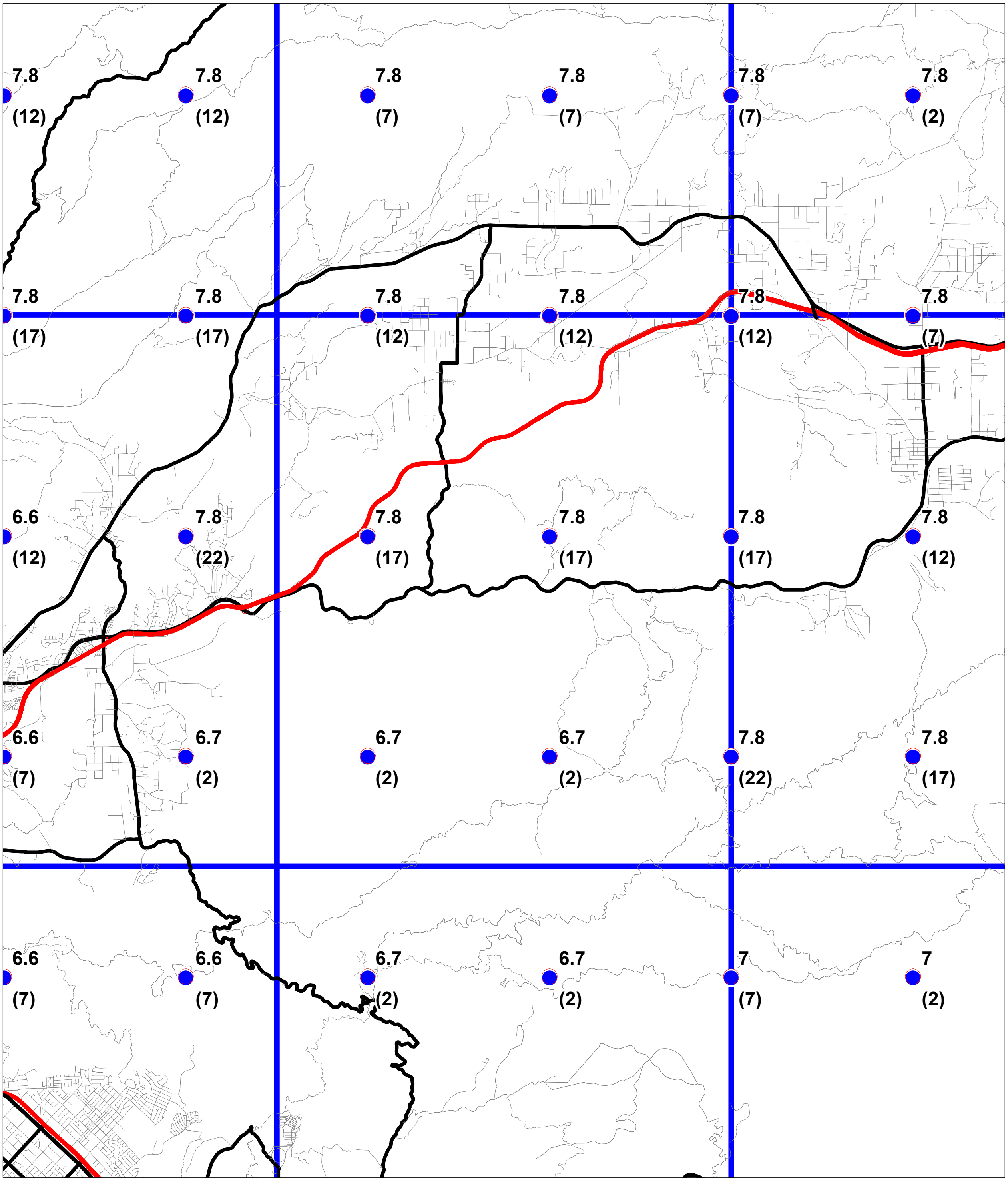
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

AGUA DULCE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

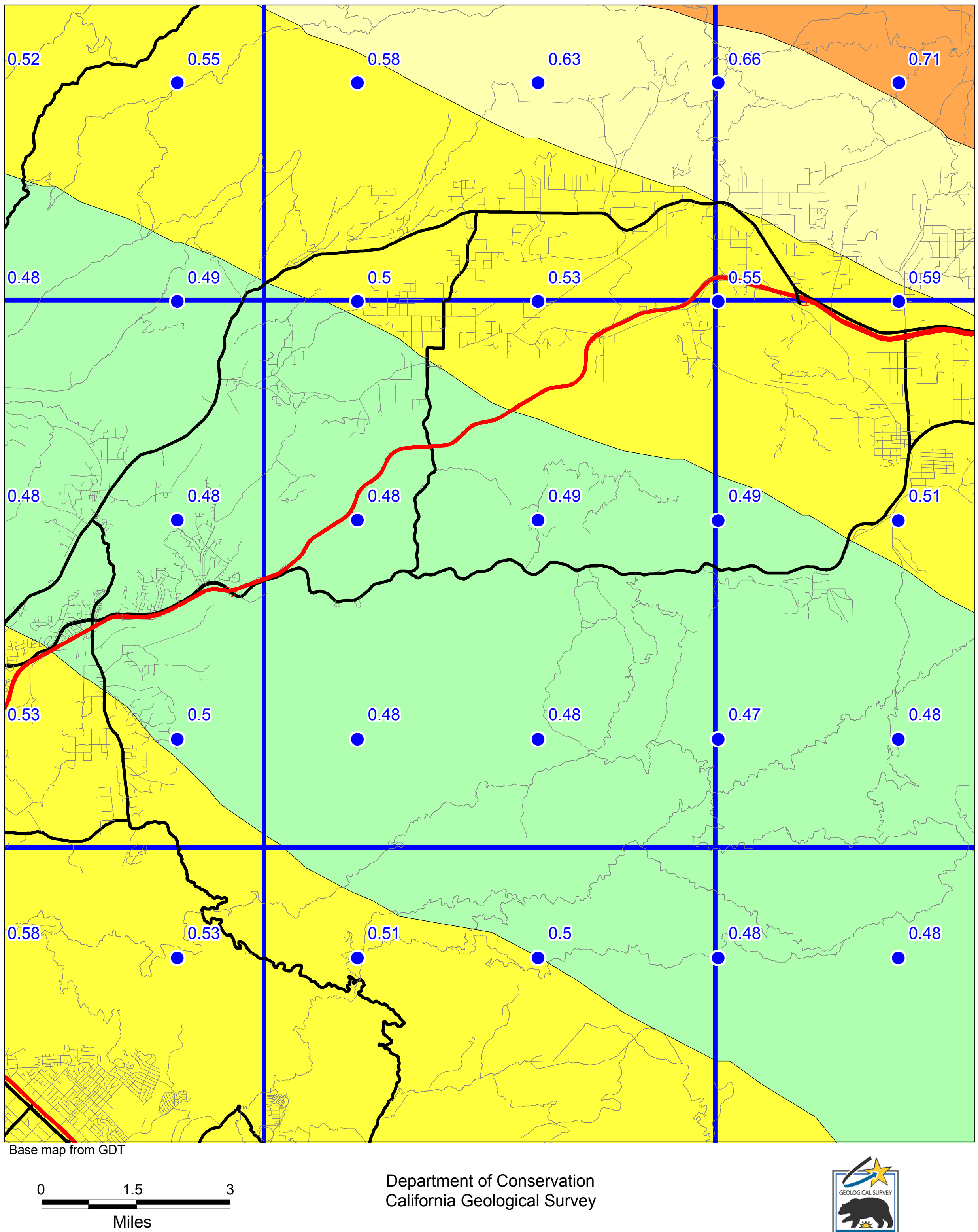
Figure 3.4

AGUA DULCE 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Department of Conservation
California Geological Survey

Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50 percent of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

REFERENCES

Boore, D.M., Joyner, W.B. and Fumal, T.E., 1997, Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: Seismological Research Letters, v. 68, p. 154-179.

California Department of Conservation, Division of Mines and Geology, 1997, Guidelines for evaluating and mitigating seismic hazards in California: Special Publication 117, 74 p.

Campbell, K.W., 1997, Attenuation relationships for shallow crustal earthquakes based on California strong motion data: Seismological Research Letters, v. 68, p. 180-189.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: Bulletin of the Seismological Society of America, v. 85, no. 5, p. 1645-1649.

Cramer, C.H., Petersen, M.D. and Reichle, M.S., 1996, A Monte Carlo approach in estimating uncertainty for a seismic hazard assessment of Los Angeles, Ventura, and Orange counties, California: Bulletin of the Seismological Society of America, v. 86, p. 1681-1691.

International Conference of Building Officials (ICBO), 1997, Uniform Building Code: v. 2, Structural engineering and installation standards, 492 p.

Jennings, C.W., *compiler*, 1994, Fault activity map of California and adjacent areas: California Department of Conservation, Division of Mines and Geology, California Geologic Data Map Series, map no. 8.

Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open-File Report 96-08; also U.S. Geological Survey Open-File Report 96-706, 33 p.

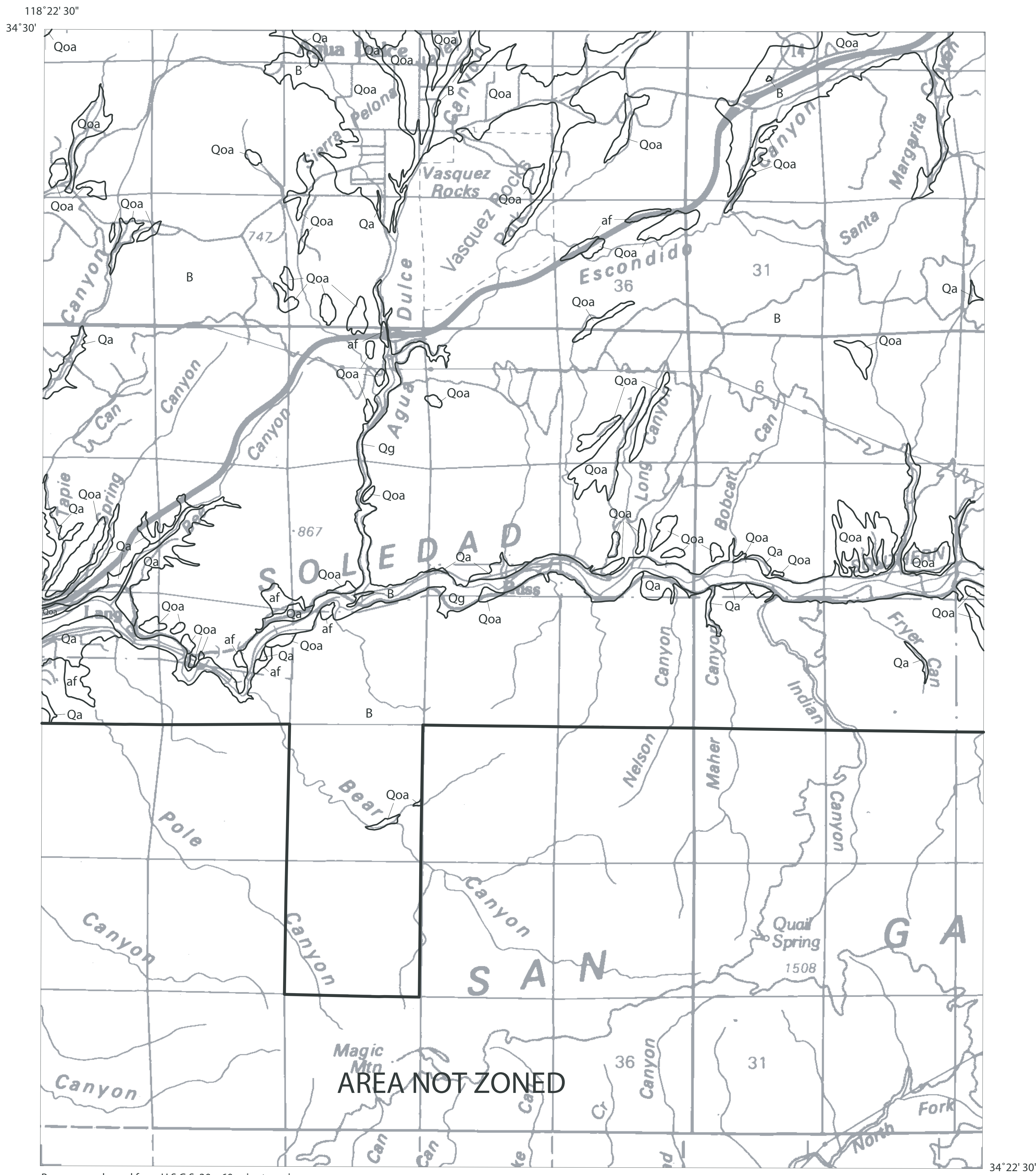
Real, C.R., Petersen, M.D., McCrink, T.P. and Cramer, C.H., 2000, Seismic Hazard Deaggregation in zoning earthquake-induced ground failures in southern California: Proceedings of the Sixth International Conference on Seismic Zonation, November 12-15, Palm Springs, California, EERI, Oakland, CA.

Sadigh, K., Chang, C.-Y., Egan, J.A., Makdisi, F. and Youngs, R.R., 1997, SEA96- A new predictive relation for earthquake ground motions in extensional tectonic regimes: Seismological Research Letters, v. 68, p. 190-198.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, Earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

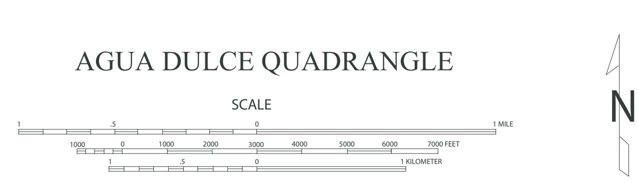
Youd, T.L. and Idriss I.M., 1997, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: Technical Report NCEER-97-0022, 40 p.

Youngs, R.R., Chiou, S.-J., Silva, W.J. and Humphrey, J.R., 1997, Stochastic point-source modeling of ground motions in the Cascadia Region: Seismological Research Letters, v. 68, p. 74-85.



Base map enlarged from U.S.G.S. 30 x 60-minute series

AGUA DULCE QUADRANGLE



B = Pre-Quaternary bedrock.

See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

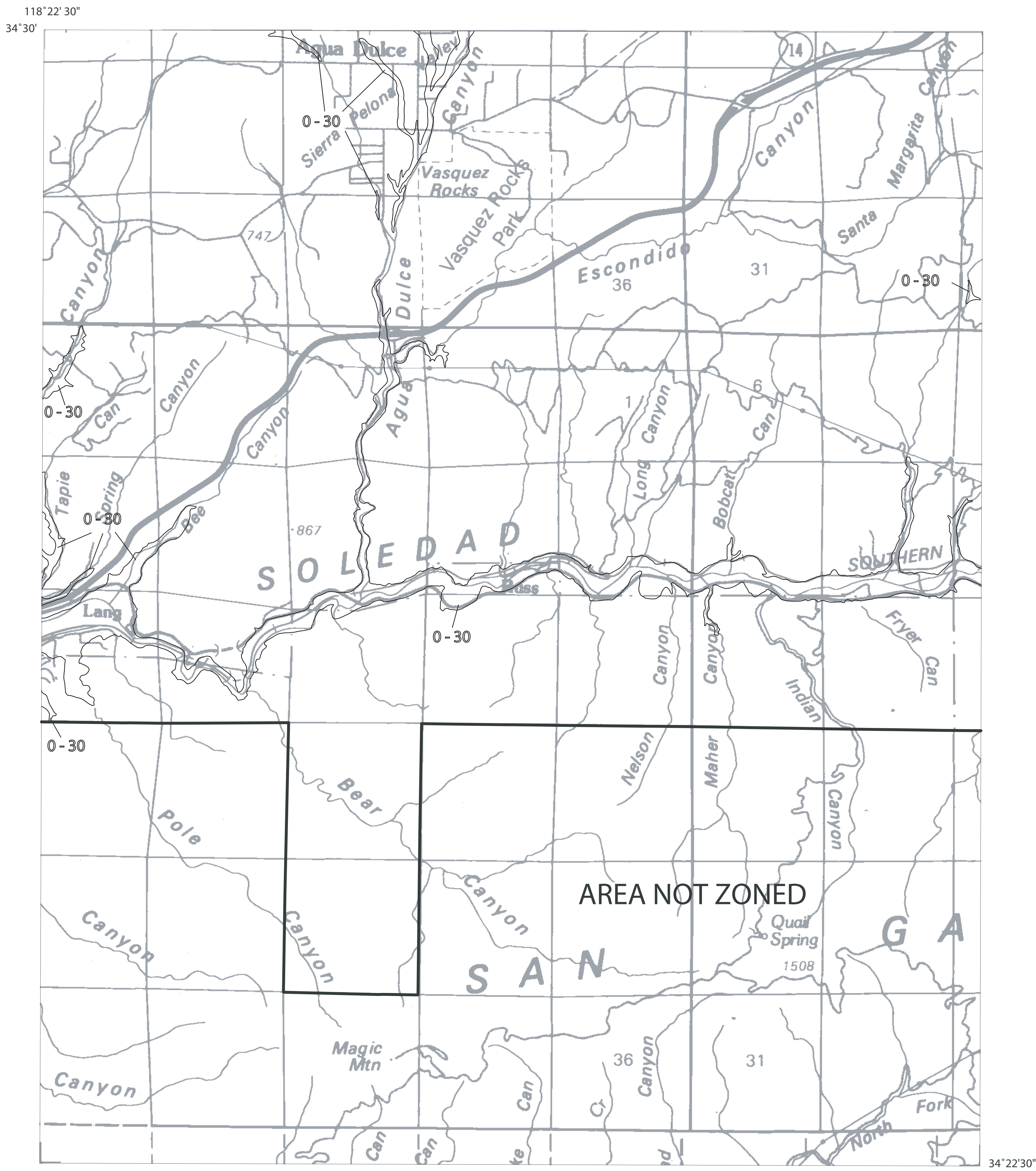
Plate 1.1 Quaternary Geologic Map of the Agua Dulce 7.5-minute Quadrangle, California.

Modified from Dibblee, 1996.

CALIFORNIA GEOLOGICAL SURVEY
JAMES F. DAVIS, STATE GEOLOGIST

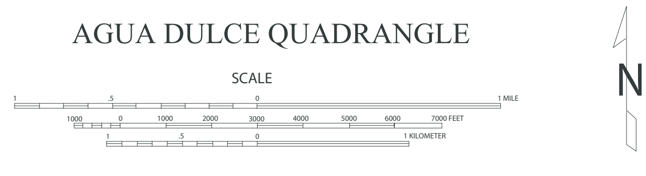
STATE OF CALIFORNIA-GRAY DAVIS, GOVERNOR
THE RESOURCES AGENCY-MARY D. NICHOLS, SECRETARY
DEPARTMENT OF CONSERVATION-DARRYL W. YOUNG, DIRECTOR

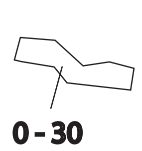
Agua Dulce Quadrangle Plate 1.2
SEISMIC HAZARD ZONE REPORT 085



Base map enlarged from U.S.G.S. 30 x 60-minute series

AGUA DULCE QUADRANGLE

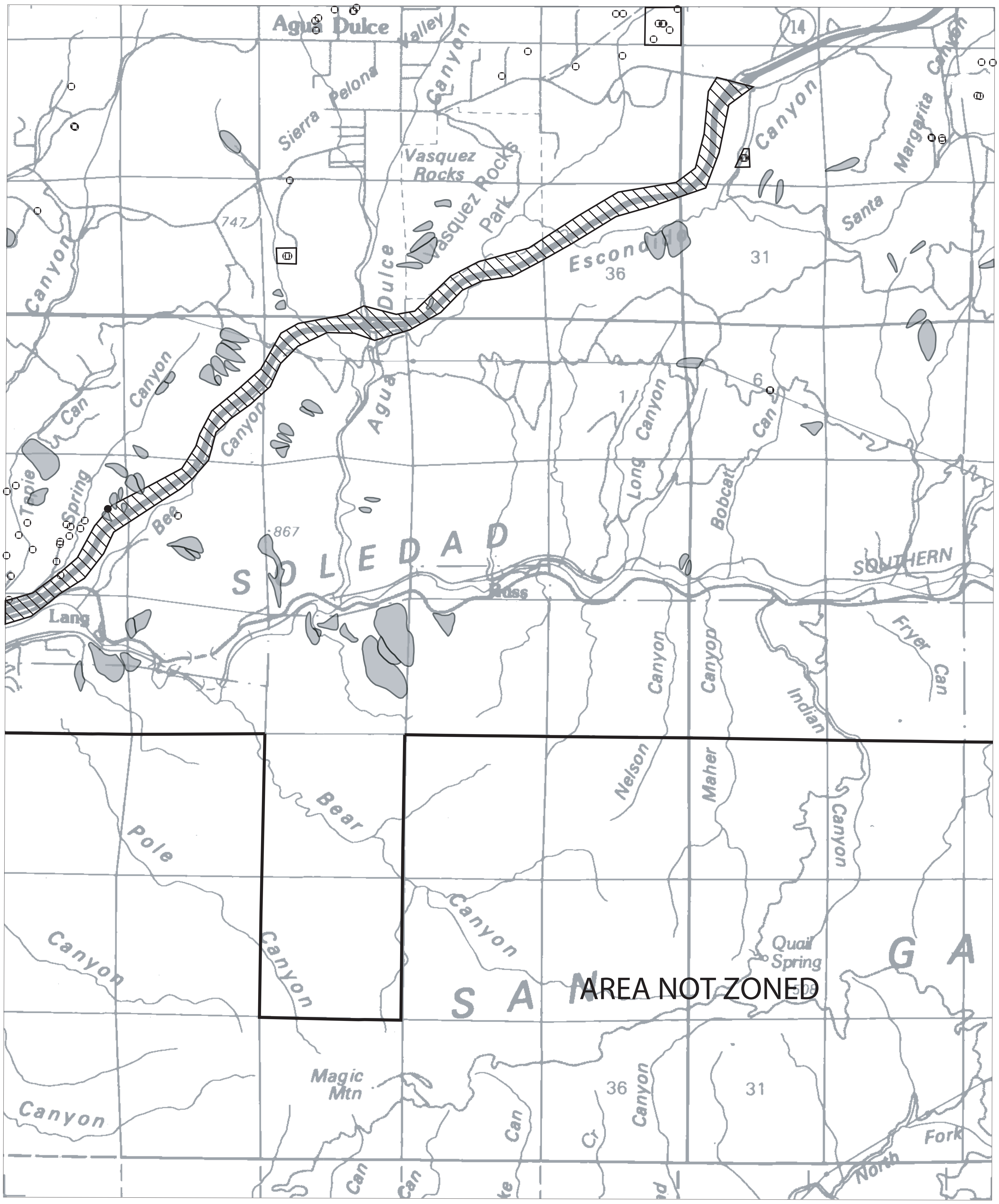




Depth to ground water, in feet

Plate 1.2 Depth to historically high ground water, Agua Dulce 7.5-minute Quadrangle, California

118°22'30'
34°30'



34°22'30"
118°15'

Base map enlarged from U.S.G.S. 30 x 60-minute series

AGUA DULCE QUADRANGLE

SCALE
1 .5 0 1 MILE
1000 0 2000 4000 6000 FEET
1 .5 0 1 KILOMETER

N

● Shear test sample location
Landslide
Area of significant grading
Tract report with multiple shear tests

Plate 2.1 Landslide inventory, shear test sample locations, and areas of significant grading, Agua Dulce 7.5-Minute Quadrangle, California